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(54) Liquid crystal display device.

(57) The invention relates to a liquid crystal display device having electrodes which form a picture element matrix and generate an electric field substantially parallel to the substrate; it is characterized in that it has a brightness recovering time of not greater than 5 min, the brightness recovering time being the time until the brightness of a displayed portion that has been displayed for 30 min and is turned off, returns to the background brightness. The products $(\epsilon_r\rho)_{LC}$, $(\epsilon_r\rho)_{AF}$ and/or $(\epsilon_r\rho)_{PAS}$ of the specific dielectric constant ϵ_r and the specific resistivity ρ of the liquid crystal layer (LC), the orienting film (AF) and/or the insulating film (PAS) are preferably within the range of 1×10^9 to 8×10^{15} Ω•cm.

FIG. 1(a)

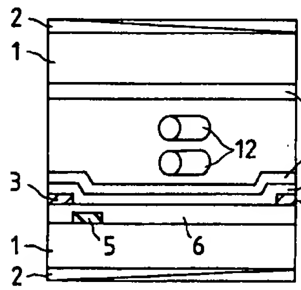
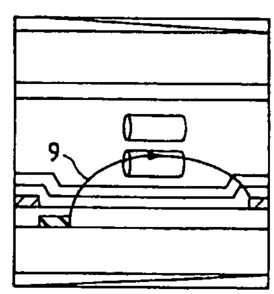


FIG. 1(b)



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The present invention relates to a liquid crystal display device of high picture quality with substantially eliminated residual image.

In prior art liquid crystal display devices, two opposite transparent electrodes formed on the two substrates were used as electrodes for driving the liquid crystal layer. In accordance therewith, a display method based on the twisted nematic display has been adopted, wherein the liquid crystal display is operated by applying an electric field approximately in vertical direction to the substrate boundary planes. On the other hand, there has been known a method wherein the direction of the electric field is approximately parallel to the substrates; in this method, a pair of comb-like electrodes is used as disclosed, for example, in JP-B-63-21907 and WO91/10936. In these cases, the electrodes are not necessarily transparent, and opaque metallic electrodes having high conductivity are used. However, the above prior art is silent about the liquid crystal material, the orienting film and the insulating film, which are necessary for obtaining a high picture quality when driving the display system, wherein the electric field is supplied to the liquid crystal in an approximately parallel direction to the substrate plane (hereinafter called in-plane switching system), with active matrix driving or simple matrix driving.

When a character or a drawing is displayed in the display plane, the image of the character or the drawing remains for a while in the display plane even after erasing, and sometimes it causes an uneven display called afterimage. The afterimage is a common problem which leads to insufficient image quality both for display methods wherein the electric field is supplied in perpendicular direction or the in-plane switching system. Especially, in the case of the in-plane switching system, the afterimage effect occurs more easily than in cases wherein the applied electric field is perpendicular to the substrate plane.

It is the object of the present invention to provide a liquid crystal display device of high picture quality with substantially eliminated residual image.

The above object is achieved according to claim 1; the dependent claims relate to preferred embodiments.

The liquid crystal display device of the present invention (hereinafter referred to as a liquid crystal display device of an in-plane switching system) comprises:

display picture elements composed of electrodes on a substrate,

an orienting film for the liquid crystal layer formed on the substrate directly or via an insulating layer,

the substrate being arranged such as to face another transparent substrate on which another orienting film is formed,

the liquid crystal layer being held between the above two substrates,

the electrodes being arranged such as to generate an electric field substantially parallel to the substrate and to the liquid crystal layer, and being connected to external control means, and

polarizing means for changing the optical characteristics of the liquid crystal layer;

it is characterized in that it has

a brightness recovering time of not greater than 5 min, the brightness recovering time being the time until the brightness of a displayed portion that has been displayed for 30 min and is then turned off, returns to the background brightness.

In liquid crystal display devices of an in-plane switching system, the display picture elements are composed of scanning signal electrodes and image signal electrodes. They may further be provided with picture element electrodes and active elements, which are desirably, however, this feature does not restrict the present invention.

The orienting film is a film having the function to orient the liquid crystal. The term insulating film means a film for electrically insulating, however, the film concurrently can also have the function to protect an electrode.

In accordance with a preferred embodiment, the respective products $(\epsilon_r\rho)_{LC}$, $(\epsilon_r\rho)_{AF}$ and/or $(\epsilon_r\rho)_{PAS}$ of the specific dielectric constant ϵ_r and the specific resistivity ρ of the liquid crystal layer (abbreviated as LC), the orienting film (abbreviated as AF) and/or the insulating film (abbreviated as PAS) are within the range of 1×10^9 to 8×10^{15} Ω•cm.

Here, the dielectric constant of the liquid crystal layer, ϵ_r, means the average dielectric constant expressed by the following equation:

$$\epsilon_r = (\epsilon\| + 2\epsilon\perp)/3,$$

where $\epsilon\|$ is the dielectric constant in the molecular major axis direction, and $\epsilon\perp$ is the dielectric constant in the minor axis direction of the molecule.

When $\epsilon_r\rho$ is less than 1×10^9 Ω•cm, the device does not have sufficient insulating properties, and a sufficient voltage keeping rate.

According to a second preferred embodiment of the liquid crystal display device of an in-plane switching system according to the present invention the orienting film and/or the insulating film have values of the surface resistance of 3×10^{11} to 2.5×10^{18} Ω/□.

When the values of surface resistance are less than 3×10^{11} Ω/□, the device has insatisfactory insulating properties and voltage keeping rate.

According to a third preferred embodiment, the respective products $(\epsilon_r\rho)_{LC}$, $(\epsilon_r\rho)_{AF}$ and/or $(\epsilon_r\rho)_{PAS}$ of the specific dielectric constant ϵ_r and the specific resistivity ρ of the liquid crystal layer, the orienting film and/or the insulating film mutually have an approximately similar value.

According to a fourth preferred embodiment, the respective products have values in the range of 1×10^9 to 8×10^{15} $\Omega \cdot cm$.

In accordance with a fifth preferred embodiment, the ratio of the maximum value to the minimum value of the respective products $(\epsilon_r\rho)_{LC}$, $(\epsilon_r\rho)_{AF}$ and/or $(\epsilon_r\rho)_{PAS}$ of the specific dielectric constant ϵ_r and the specific resistivity ρ of the liquid crystal layer, the orienting film and/or the insulating film is 1 to 100.

According to a sixth preferred embodiment, the respective products $(\epsilon_r\rho)_{LC}$, $(\epsilon_r\rho)_{AF}$ and/or $(\epsilon_r\rho)_{PAS}$ of the specific dielectric constant ϵ_r and the specific resistivity ρ of the liquid crystal layer, the orienting film and/or the insulating film have a relationship expressed by the following equations (1) to (3):

$$0.1 \leq (\epsilon_r\rho)_{LC}/(\epsilon_r\rho)_{AF} \leq 10 \qquad (1)$$

$$0.1 \leq (\epsilon_r\rho)_{LC}/(\epsilon_r\rho)_{PAS} \leq 10 \qquad (2)$$

$$0.1 \leq (\epsilon_r\rho)_{AF}/(\epsilon_r\rho)_{PAS} \leq 10 \qquad (3).$$

According to a seventh preferred embodiment of the present invention, the sum of the film thickness of the orienting film and of the insulating film on the substrate is 0.5 to 3 μm.

According to an eighth preferred embodiment, the device is provided with

input means for information,

means for calculating or processing the information,

a device for the output of the calculated or processed information,

a memory device, and

an internal power source.

In the liquid crystal display device of the present invention, the thickness of the insulating film is preferably in a range of 0.4 to 2 μm.

Further, in the liquid crystal display device of the present invention, the orienting film is preferably made of an organic material, and the insulating film is preferably made of an inorganic material. In accordance with another preferred embodiment, the orienting film is made of an organic material, and the insulating film has a double-layer structure made of and inorganic material and an organic material. According to the still another preferred embodiment, the orienting film is made of an organic material, and the insulating film is made of an inorganic material, and the orienting film made of the organic material is preferably thicker than the insulating material made of the inorganic material.

Further, both the orienting film and the insulating film are preferably composed of an organic material, and both the orienting film and the insulating film are preferably composed of the same material. Furthermore, the surface plane of the orienting film which abuts on the liquid crystal is preferably flat.

In order to realize color displays having a high picture quality, a color filter is preferably provided on either one of the substrates, and the insulating film is preferably provided between the color filter and the liquid crystal layer. Further, a film having the function to flatten steps on the color filter and composed of an organic material is preferably provided, and a film composed of inorganic material is preferably formed on the film composed of the organic material. Furthermore, the orienting film is preferably provided on the substrate having the color filter by the intermediate of a layer composed of an inorganic material.

In the following, the present invention will be described with reference to the drawings.

Figs. 1(a) to 1(d) are schematic illustrations for explaining the operation of the liquid crystal in a liquid crystal display device based on in-plane switching in accordance with the present invention,

Fig. 2 is a schematic illustration indicating angles formed by the orienting direction of the molecular longitudinal axis on the boundary plane to the electrical field direction, and by the transmission axis of a polarizer to the electrical field direction in a liquid crystal display device supplied with a horizontal electric field to the substrate, in accordance with the present invention,

Figs. 3 to 6 are plan views and cross sections of picture element units,

Fig. 7 is a diagram indicating a typical example of the system composition of a liquid crystal display device relating to the present invention,

Figs. 8 are schematic illustrations indicating the refraction law of electric force lines, and the variation of the horizontal electric field strength in a liquid crystal layer in dependence of the relative dielectric constant and the respective layer thickness,

Fig. 9(a) is a graph indicating relationships between the maximum value of products $\epsilon\rho$ of the respective specific resistivity ρ and the specific dielectric constant ϵ and residual image characteristics of liquid crystal, insulating film, and orienting film,

Fig. 9(b) is a graph indicating relationships between the ratio of the maximum value and the minimum value of products $\epsilon\rho$ of the respective

specific resistivity ρ and the specific dielectric constant ϵ and residual image characteristics of liquid crystal, insulating film, and orienting film,

Fig. 10(a) is a graph indicating the relationship between the sum of film thickness of the insulating film and of the orienting film, and results of residual image evaluation,

Fig. 10(b) is a graph indicating the relationship between the sum of film thickness of the insulating film and of the orienting film, and the transmission factor, and

Figs. 11 are model graphs indicating relationships between the charging process and the discharging process of electric charge and residual image characteristics.

Hereinafter, the principle of in-plane switching system, wherein an electric field is applied in a direction parallel to the substrate, and subsequently, the operation of display devices of the present invention will be explained.

At the beginning, definitions of the angle ϕ_P, which is the angle formed by the polarized light transmitting axis of a polarizer with the direction of the electric field, and the angle ϕ_{LC}, which is the angle formed by the direction of the liquid crystal major axis (optical axis) at the vicinity of the liquid crystal boundary with the direction of the electric field are shown in Fig. 2. The polarizer and the liquid crystal boundary exist at the upper side and at the lower side of the device.

Therefore, the angles are expressed as ϕ_{P1}, ϕ_{P2}, ϕ_{LC1},and ϕ_{LC2}, if necessary. Fig. 2 corresponds to a front view of the device of Fig. 1 which is explained later.

Figs. 1(a) and 1(b) are side cross sections indicating the liquid crystal operation in a liquid crystal panel of the present invention, and Figs. 1(c) and 1(d) are front views of the respective Figs. 1(a) and 1(b). In Fig. 1, the active elements are omitted. Further, in accordance with the present invention, stripe-shaped electrodes are provided such as to form a plurality of picture elements, but only one picture element is shown in Fig. 1. A side cross section of a cell under no applied voltage is shown in Fig. 1(a), and the front view of Fig. 1(a) is shown in Fig. 1(c). Linear signal electrodes 3, 4, and a common electrode 5 are formed at the inner side of one pair of transparent substrates 1, an insulating film 7 is provided on the substrates and the electrodes, and an orienting film 8 is provided and processed for orientation on the insulating film 7. A liquid crystal composition is held between the substrates. A bar-shaped liquid crystal molecule 12 of the liquid crystal layer is oriented so as to have a small angle to the longitudinal direction of the stripe-shaped electrodes, that is $45° < \phi_{LC} < 135°$, or, $-45° < \phi_{LC} < -135°$, when no electric field is applied. An example is explained hereinafter when an orienting direction of the liquid crystal molecule at the upper and the lower boundaries is parallel, that is $\phi_{LC1} = \phi_{LC2}$. Further, dielectric anisotropy of the liquid crystal composition is assumed as positive.

Next, when an electric field 9 is supplied, the liquid crystal molecule changes its orienting direction to the direction of the electric field as shown in FIGs. 1(b) and 1(d). Therefore, optical transmission becomes changeable by applying electric field when an polarizer 2 is arranged at a designated angle 11. As explained above, in accordance with the present invention, a display giving contrast becomes possible without the transparent electrodes. The dielectric anisotropy of the liquid crystal composition is assumed as positive in the present description, but negative anisotropy is also usable. In a case of the negative anisotropy, the liquid crystal molecule is oriented at first oriented condition so as to have a small angle, ϕ_{LC}, to a vertical direction to the longitudinal direction of the stripe-shaped electrodes, that is -45 degrees < ϕ_{LC} < 45 degrees, or, 135 degrees < ϕ_{LC} < 225 degrees.

In FIG.1, an example wherein a common electrode is a different layer from the signal electrode and the picture element electrode is shown, but the common electrode can be the same layer with the signal electrode and the picture element electrode. A typical example of picture element structure when the common electrode is the same layer with the picture element electrode is shown in FIG. 3, and typical examples of picture element structure when the common electrodes are different layers from the picture element electrodes are shown in FIGs. 4 and 5. Further, even if the common electrode is not provided, the scanning electrode can be given the same function as the function of the common electrode. However, the gist of the present invention explained hereinafter is in insulating materials for composing the liquid crystal element, and is applicable to various electrode structures and thin film transistor structures.

As explained in the above first means, a liquid crystal display device having a high picture quality with substantially eliminated residual images can be obtained by making a necessary time for recovering brightness of the display device after displaying an identical drawing pattern for 30 minutes less than five minutes. The residual images are induced when polarization is generated in the liquid crystal layer, the orienting film, or the insulating film by any reason. Therefore, the residual images can be reduced concretely, as explained in the above second means, by making respective products ($(\epsilon_r\rho)_{LC}$, $(\epsilon_r\rho)_{AF}$, and/or $(\epsilon_r\rho)_{PAS}$) of a specific dielectric constant ϵ_r and a specific resistivity ρ of respective the liquid crystal layer, the orienting

film, and/or the insulating film equals or less than 8 x 10^{15} Ω•cm, because accumulated electric charge can be relaxed quickly. A model graph indicating the principle of residual image reduction in the above case is shown in FIG. 11(a). That means, the residual image can be reduced because relaxing speed is fast even if electric charge is accumulated, and the electric charge is discharged quickly. Further, the residual image can be reduced by decreasing the accumulated electric charge as shown in FIG. 11(b) even if the relaxing speed is slow. Therefore, the residual image problem can be improved by making respective surface resistance of the orienting film and/or the insulating film equals or less than 2.5 x 10^{18} Ω/□ in order to decrease accumulating electric charge as stated in the above third means. Furthermore, as stated in the above fourth, sixth, and seventh means, the residual image can be reduced further by substantially equalizing products of specific dielectric constant ϵ_r and specific resistivity ρ of the liquid crystal layer, the orienting film, and the insulating layer. As described previously, the residual image is induced when polarization is generated in the liquid crystal layer, the orienting film, or the insulating film by any reason. And, the polarization in the respective layer and films interfere each other such as the polarization generated in the orienting film generates secondary polarization in the liquid crystal layer.

For instance, if any polarization remains in the orienting film in a relaxation process of polarization of liquid crystal layer, the polarization in the orienting film effects to the liquid crystal layer for preventing the relaxation of the polarization in the liquid crystal layer. Accordingly, in order to proceed the relaxation generated in the respective layer or films without interfering each other, respective relaxation time must be equal. The inventors of the present invention found that the above described principle can be established significantly in the method wherein the electric field is supplied in a direction parallel to the substrate, that is, the in-plane switching method. In the in-plane switching method, electric equivalent circuits corresponding to the respective liquid crystal layer, the insulating film, and the orienting film are connected in parallel.

Therefore, for instance, when a product ($\epsilon_r\rho$) of specific dielectric constant ϵ_r and specific resistivity ρ for the orienting film or the insulating film is larger than that for the liquid crystal layer, residual voltage in the orienting film or the insulating film is supplied to the liquid crystal layer as an extra voltage, and consequently, residual image are induced. Furthermore, in consideration that resistance R can be expressed by the equation, $R = \rho d/S$ (where ρ: specific resistivity, d: length in the direction of the electric field, S: vertical cross section area to the electric field), the in-plane switching system has significantly larger resistance in the element structure than the method wherein the electric field is supplied to the substrate perpendicularly. That means, residual direct current component in the in-plane switching system is remarkably large. In the above described case, a combination of the forth means, the sixth means or the seventh means with the second means as the fifth means makes it possible to relax the accumulated charge in a short time without interfering the liquid crystal layer, the orienting film, and/or the insulating film mutually in the relaxing course of the accumulated charge.

Therefore, the combination is an effective means for reducing the residual image.

The above principle can be established in the in-plane switching system irrelevant to whether simple matrix driving method nor active matrix driving method.

Further, resistance components of the orienting film and the insulating film at each picture elements can be decreased by making a sum of thicknesses of a film having a function to orient liquid crystal (orienting film) and a film having functions to insulate electrically and to protect the electrodes group (insulating film) within a range of from 0.5 µm to 3 µm, desirably from 0.7 µm to 2.8 µm. Actually, the thickness of the insulating film is desirably selected in a range from 0.4 µm to 2 µm as described in the above tenth means in order to deduce additional effects of the steps on the substrate whereon the electrodes group is mounted. As explained previously, in a method wherein a direction of electric field supplied to the liquid crystal is approximately parallel to the substrate plane, electric equivalent circuits corresponding to the respective liquid crystal layer, the insulating film, and the orienting film are connected in parallel.

Accordingly, voltage remained in the orienting film and the insulating film is supplied directly to the liquid crystal layer. Considering that residual images are generated by supplying residual voltage in the orienting film and the insulating film to the liquid crystal layer, the residual voltage in the orienting film and the insulating film can be reduced and excessive voltage supplied to the liquid crystal layer can be eliminated by decreasing resistance components equivalent to the orienting film and the insulating film at each picture elements. In order to decrease the resistance components in the orienting film and the insulating film, the film thickness of the orienting film and of the insulating film must be increased for enlarging the cross sectional area perpendicular to the direction of the electric field.

The insulating film can be formed with reliable inorganic material, and the orienting film can be formed with organic material. Further, the insulating film can be formed in a double layers structure which is composed of an inorganic material layer and a relatively easily shapable organic material layer.

FIG. 8 is a schematic illustration indicating variation in line of electric force in a liquid crystal layer depending on magnitude of dielectric constant in each layers. The smaller are the dielectric constants in the orienting film and the insulating film than the dielectric constant of the liquid crystal layer, the more ideal in-plane switching can be realized.

Accordingly, an electric field component horizontal to the substrate plane can be utilized effectively by replacing a layer of inorganic material with a layer of organic material having a low dielectric constant as much as possible. Further, the above effect can be realized by making the insulating film with organic material. Furthermore, fabricating the insulating film and the orienting film with a same material realizes a high efficiency in a manufacturing process. In order to improve picture quality in a liquid crystal display device, flattening surface plane of the orienting film abutting on the liquid crystal is important. By the flattening, steps at the surface plane can be eliminated, and light leakage can be suppressed by making effects of rubbing uniform all through the surface plane.

In order to realize color display by the in-plane switching system, it is necessary that only the insulating film must be inserted between a color filter and the liquid crystal layer. Because, a conductive body existing in the interval between the color filter and the liquid crystal destroys a horizontal electric field.

Generally, an organic material such as epoxy resin is used as a flattening film for color filter, and transparent electrodes are provided on the flattening film. However, the transparent electrodes are not necessary in the in-plane switching system as stated previously, the flattening film contacts directly with the orienting film. In this case, printability of the orienting film causes sometimes troubles. Therefore, a layer of inorganic material such as silicon nitride provided on an upper portion of the flattening film is effective in improving printability. The color filter is not necessarily provided on facing planes of the substrates whereon the electrodes group existed, rather, preciseness of alignment can be improved by providing the color filter on the substrate plane whereon the active elements and electrodes group are mounted.

Detailed Description of the Embodiments

Embodiment 1

FIGs. 3 indicate a structure of electrode for a picture element unit in the first embodiment of the present invention. A scanning signal electrode 13 made of aluminum was formed on a polished glass substrate, and surface of the scanning signal electrode was coated with alumina film, i.e. anodic oxide film of aluminum. A gate silicon nitride (gate SiN) film 6 and an amorphous silicon (a-Si) film 14 were formed so as to cover the scanning signal electrode, and a n-type a-Si film, a picture element electrode 4 , and an image signal electrode 3 were formed on the a-Si film. Further, a common electrode 5 was provided in the same layer as the picture element electrode and the image signal electrode. The picture element electrode and the signal electrode had a structure, as shown in FIG. 3, parallel to the strip-shaped common electrode and crossing across the scanning signal electrode, and a thin film transistor 15 and a group of metallic electrodes were formed at one end of the substrate. In accordance with the above structure, an electric field 9 could be supplied between the picture element electrode and the common electrode at one end of the substrate in a direction approximately parallel to substrate plane. All of the electrodes on the substrate were made of aluminum. But any of metallic material having low electric resistance such as chromium, copper, and others can be used. The number of the picture elements was 40 (x3) x 30 (i.e. n = 120, m = 30), and pitches of the picture elements were 80 μm in width (i.e. between common electrodes) and 240 μm in length (i.e. between gate electrodes). Width of the common electrode was made as 12 μm, which was narrower than a gap between adjacent common electrodes, in order to secure a large opening fraction. Three strip-shaped color filters of respectively red (R), green (G), and blue (B) were provided on a substrate facing to the substrate having a thin film transistor. On the color filters, transparent resin was laminated in order to flatten surface of the color filter. As material for the above transparent resin, an epoxy resin was used. Further, an orienting controlling film made of polyamide group resin was applied on the transparent resin. A driving LSI was connected to the panel as shown in FIG. 7, a vertical scanning circuit 20 and an image signal driving circuit 21 were connected to TFT substrate, and the active matrix was driven by being supplied scanning signal voltage, image signal voltage, and timing signal from a power source circuit and a controller 22.

Drawn directions of the upper and the lower boundary planes were approximately parallel mutu-

ally, and formed an angle of 15 degrees ($\phi_{LC1} = \phi_{LC2} = 15^\circ$) to a direction of supplied electric field (FIG. 2). A gap d was kept by holding dispersed spherical polymer beads between the substrates at 6.5 μm interval under a liquid crystal filled condition. The panel was held between two polarizer (made by Nitto Denko Co., G1220DU), polarizing light transmitting axis of one of the polarizer was selected as approximately parallel to a rubbing direction, i.e. $\phi_{P1} = 15^\circ$, and the axis of another polarizer was selected as perpendicular to the rubbing direction, i.e. $\phi_{P2} = -75^\circ$. Accordingly, a normal closed characteristics was obtained.

Between the substrates, a liquid crystal ZLI-2806 (made by Merck Co.) containing trans,trans-4,4'-dipentyl-trans-1,1'-dicyclohexane-4-carbonitrile as for a main component having a negative dielectric anisotropy $\Delta\epsilon$ was held. The liquid crystal had a specific resistivity of 5.1 x 10^{11} Ωcm and an average specific dielectric constant of 6.5. While, silicon nitride (SiN) was used as for an insulating film, and its specific resistivity was 2.5 x 10^{13} Ωcm and specific dielectric constant was 8. As for an orienting film, a polyamide orienting film made from 2,2-bis[4-(p-aminophenoxy)-phenylpropane and pyromellitic acid dianhydride was used, and its specific resistivity was 7.5 x 10^{13} Ωcm and its average specific dielectric constant was 2.9. Accordingly, respective products ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the liquid crystal layer, the insulating film, and the orienting film respectively was less than 8 x 10^{15} Ωcm, and the ratio of the maximum value and the minimum value of the three bodies, ($(\epsilon_r\rho)_{max} / (\epsilon_r\rho)_{min}$), was less than 100.

Residual image was evaluated by visual observation with five rankings. An identical figure pattern was displayed for thirty minutes, and samples were classified by necessary time for recovering brightness after switching off the display. Samples were evaluated and classified as follows;

Sample of rank 5 was the one necessitated more than five minutes for recovering brightness, rank 4 was from one minute to less than five minutes, rank 3 was from 30 seconds to less than one minute, rank 2 was less than 30 seconds but generation of any residual image was felt, and rank 1 was no residual image at all.

The sample in the present embodiment 1 was evaluated as rank 1 because any residual image was not observed at all.

The present invention relates to specific dielectric constant and specific resistivity of the insulating material composing the element, and accordingly, the present invention is applicable to various structures of electrodes and TFTs.

Embodiment 2

FIGs. 4 indicate a structure of electrode for a picture element unit in the second embodiment of the present invention. A scanning signal electrode 13 and a common electrode 5 made of aluminum was formed on a polished glass substrate, and surface of the scanning signal electrode was coated with alumina film, i.e. anodic oxide film of aluminum. A gate silicon nitride (gate SiN) film 6 was formed so as to cover the scanning signal electrode and the common electrode. Subsequently, an amorphous silicon (a-Si) film 14, and n-type a-Si film on the a-Si film were formed. Further, a picture element electrode 4 , and a signal electrode 3 were formed. Accordingly, the picture element electrode and the common electrode were in different layers mutually. The picture element electrode had a H-shaped structure, as shown in FIG. 4, and the common electrode had a cruciform structure, a part of each electrodes had a structure working as capacitance elements. In accordance with the above structure, an electric field could be supplied between the picture element electrode and the common electrode at one end of the substrate in a direction approximately parallel to substrate plane. All of the electrodes on the substrate were made of aluminum. But any of metallic material having low electric resistance such as chromium, copper, and others can be used. The number of the picture elements was 320 x 160, and pitches of the picture elements were 100 μm in width (i.e. between signal electrodes) and 300 μm in length (i.e. between scanning electrodes). Driving transistors were connected to the panel as shown in FIG. 7, a vertical scanning circuit 20 and an image signal driving circuit 21 were connected to TFT substrate, and the active matrix was driven by being supplied scanning signal voltage, image signal voltage, and timing signal from a power source circuit and a controller 22.

Drawn directions of the upper and the lower boundary planes were approximately parallel mutually, and formed an angle of 105 degrees ($\phi_{LC1} = \phi_{LC2} = 105^\circ$) to a direction of supplied electric field (FIG. 2). A gap d was kept by holding dispersed spherical polymer beads between the substrates at 4.2 μm interval under a liquid crystal filled condition. The panel was held between two polarizer (made by Nitto Denko Co., G1220DU), polarizing light transmitting axis of one of the polarizer was selected as approximately parallel to a rubbing direction, i.e. $\phi_{P1} = 105^\circ$, and the axis of another polarizer was selected as perpendicular to the rubbing direction, i.e. $\phi_{P2} = 15^\circ$. Accordingly, a normal closed characteristics was obtained.

Between the substrates, a liquid crystal of which main component was a compound contain-

ing three fluoro groups at terminals having a positive dielectric anisotropy $\Delta\epsilon$ was held. The liquid crystal had a specific resistivity of 5.0×10^{14} Ωcm and an average specific dielectric constant of 6.1. While, silicon nitride (SiN) was used as for an insulating film, and its specific resistivity was 3.0×10^{14} Ωcm and specific dielectric constant was 8. As for an orienting film, a polyamide orienting film made from 2,2-bis[4-(p-aminophenoxy)-phenyl-propaneand pyromellitic acid dianhydride was used, and its specific resistivity was 1.0×10^{14} Ωcm and its average specific dielectric constant was 2.9.

Accordingly, respective products ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the liquid crystal layer, the insulating film, and the orienting film respectively was less than 8×10^{15} Ωcm, and the ratio of the maximum value and the minimum value of the three bodies, $((\epsilon_r\rho)_{max} / (\epsilon_r\rho)_{min})$, was less than 100.

The active matrix type liquid crystal display device as obtained above was evaluated as rank 1 in the evaluation of residual image, and any residual image was not observed at all.

Embodiment 3

Composition of the present embodiment is the same as embodiment 2 except following subject matters;

The insulating film had a double layer structure composed of an inorganic silicon nitride (SiN) layer and organic epoxy resin layer, and a compound, RN-718 (made by Nissan Chemical Co.), was applied on the insulating film having two layers as an orienting film. The insulating film had a specific resistivity of 9.1×10^{13} Ωcm and a specific dielectric constant of 3.1. And the liquid crystal had a specific resistivity of 1.0×10^{12} Ωcm and a specific dielectric constant of 6.1.

Accordingly, respective products ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the liquid crystal layer, the insulating film, and the orienting film respectively was less than 8×10^{15} Ωcm, and the ratio of the maximum value and the minimum value of the three bodies, $((\epsilon_r\rho)_{max} / (\epsilon_r\rho)_{min})$, was less than 100.

The active matrix type liquid crystal display device as obtained above was evaluated as rank 1 in the evaluation of residual image, and any residual image was not observed at all.

Embodiment 4

FIGs. 5 indicate a structure of electrode for a picture element unit in the fourth embodiment of the present invention. A thin film transistor element 15 comprises a picture element electrode 4, a signal electrode 3, a scanning electrode 13 and amorphous silicon 14. A common electrode 5 was in the same layer as the scanning electrode, and formed by making a pattern from the same metallic layer. Further, the picture element electrode and the signal electrode were also formed by making a pattern from the same metallic layer. A capacitative element was formed of a structure holding a gate silicon nitride (gate SiN) film 6 with the picture element electrode and the common electrode in a region connecting two common electrodes 5. The picture element electrode 4 is arranged between two common electrodes 5 as shown in front cross section (FIG. 5, A-A'). Pitches of the picture elements were 69 μm in width (i.e. between signal wiring electrodes) and 207 μm in length (i.e. between scanning wiring electrodes). Width of the respective electrodes was 10 μm. While, in order to secure a large opening fraction, widths of the picture element electrode independently formed for a picture element unit and a portion extended to a longitudinal direction of signal wiring electrode of the common electrode were made narrow such as 5 μm and 8 μm, respectively. In order to realize a large opening fraction as possible, the common electrode and the signal electrode were somewhat overlapped (1 μm) via the insulating film. Accordingly, a black matrix structure 16 wherein shading was provided only in a direction along the scanning wiring electrode was formed. Consequently, a gap between the common electrode and the picture element electrode became 20 μm, and length of the opening in a longitudinal direction became 157 μm, and a large opening fraction such as 44.0 % was obtained. The number of picture elements were 320 x 160 with 320 signal wiring electrodes and 160 wiring electrodes. Driving transistors were connected to the panel as shown in FIG. 7, a vertical scanning circuit 20 and an image signal driving circuit 21 were connected to TFT substrate, and the active matrix was driven by being supplied scanning signal voltage, image signal voltage, and timing signal from a power source circuit and a controller 22.

The insulating film was composed of a single layer made by an organic epoxy resin, and a compound, RN-718 (made by Nissan Chemical Co.), was applied on the insulating film as an orienting film. In this case, the insulating film had a specific resistivity of 1.5×10^{12} Ωcm and a specific dielectric constant of 3.0. The orienting film had a specific resistivity of 4.0×10^{13} Ωcm and its specific dielectric constant was 3.1. The liquid crystal had a specific resistivity of 1.5×10^{13} Ωcm and its specific dielectric constant was 6.1.

Accordingly, respective products ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the liquid crystal layer, the insulating film, and

the orienting film respectively was less than 8 x 10^{15} Ωcm, and the ratio of the maximum value and the minimum value of the three bodies, ($(\epsilon_r\rho)_{max}$ / $(\epsilon_r\rho)_{min}$), was less than 100.

The active matrix type liquid crystal display device as obtained above was evaluated as rank 1 in the evaluation of residual image, and any residual image was not observed at all.

Embodiment 5

Composition of the present embodiment is the same as embodiment 4 except following subject matters;

A color filter was formed in the insulating film. First, silicon nitride (SiN) layer was formed, and subsequently, the color filter was provided by printing. Further, epoxy resin was applied in order to flatten the surface. Then, a compound, RN-718 (made by Nissan Chemical Co.), was applied on the insulating film as an orienting film. The insulating film of the present embodiment had a specific resistivity of 4.4 x 10^{11} Ωcm and a specific dielectric constant of 3.9. The orienting film had a specific resistivity of 4.9 x 10^{13} Ωcm and a specific dielectric constant of 3.1. And the liquid crystal had a specific resistivity of 1.6 x 10^{13} Ωcm and a specific dielectric constant of 6.1.

Accordingly, respective products ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the liquid crystal layer, the insulating film, and the orienting film respectively was less than 8 x 10^{15} Ωcm, and the ratio of the maximum value and the minimum value of the three bodies, ($(\epsilon_r\rho)_{max}$ / $(\epsilon_r\rho)_{min}$), was less than 100.

The active matrix type liquid crystal display device as obtained above was evaluated as rank 1 in the evaluation of residual image, and any residual image was not observed at all.

Embodiment 6

Composition of the present embodiment is the same as embodiment 5 except following subject matters;

In order to increase flatness of the orienting film plane abutting on the liquid crystal, thickness of the orienting film was set five times, 5000 Å, of the thickness (1000 Å) used in the above embodiment 5. Therefore, flatness of the plane was increased, steps on the plane were decreased, and lapping treatment was performed uniformly. Consequently, light leakage at the step portion was eliminated.

The active matrix type liquid crystal display device as obtained above was evaluated as rank 1 in the evaluation of residual image, any residual image was not observed at all, and contrast was improved better than that of the embodiment 5.

Embodiment 7

Composition of the present embodiment is the same as embodiment 6 except following subject matters;

Printability of polyamide orienting film on epoxy resin layer is not necessarily preferable. Therefore, silicon nitride (SiN) film, an inorganic material film, was formed on the epoxy resin which had functions to flatten the color filter and as an insulating film. In accordance with the above treatment, printability of the orienting film was improved.

The active matrix type liquid crystal display device as obtained above was evaluated as rank 1 in the evaluation of residual image, any residual image was not observed at all, contrast was improved better than that of the embodiment 5, printability of the orienting film was improved, and production yield was increased.

Embodiment 8

Composition of the present embodiment is the same as embodiment 4 except following subject matters;

A color filter was formed in the insulating film. First, silicon nitride (SiN) layer was formed, and subsequently, the color filter was provided by printing. Further, epoxy resin was applied in order to flatten the surface. Then, a compound, RN-718 (made by Nissan Chemical Co.), was applied on the insulating film as an orienting film. The insulating film of the present embodiment had a specific resistivity of 4.4 x 10^{11} Ωcm and a specific dielectric constant of 3.9. The orienting film had a specific resistivity of 4.9 x 10^{13} Ωcm and a specific dielectric constant of 3.1. And the liquid crystal had a specific resistivity of 1.6 x 10^{13} Ωcm and a specific dielectric constant of 6.1.

Accordingly, respective products ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the liquid crystal layer, the insulating film, and the orienting film respectively was less than 8 x 10^{15} Ωcm, and the ratio of the maximum value and the minimum value of the three bodies, ($(\epsilon_r\rho)_{max}$ / $(\epsilon_r\rho)_{min}$), was less than 100.

The active matrix type liquid crystal display device as obtained above was evaluated as rank 1 in the evaluation of residual image, and any residual image was not observed at all.

Embodiment 9

FIGs. 6 indicate a structure of electrode for a picture element unit in the ninth embodiment of the present invention. In the present embodiment, thin

film transistors were not provided to the picture element units. A scanning signal electrode 13 and a signal electrode 3 were in different layers mutually. Each electrodes were connected respectively to a scanning circuit driver and an image signal circuit driver, and the matrix was driven in a simple time-shared manner.

Drawn directions of the upper and the lower boundary planes were approximately parallel mutually, and formed an angle of 105 degrees (ϕ_{LC1} = ϕ_{LC2} = 105°) to a direction of supplied electric field (FIG. 2). A gap d was kept by holding dispersed spherical polymer beads between the substrates at 4.2 μm interval under a liquid crystal filled condition. The panel was held between two polarizer (made by Nitto Denko Co., G1220DU), polarizing light transmitting axis of one of the polarizer was selected as approximately parallel to a rubbing direction, i.e. ϕ_{P1} = 105°, and the axis of another polarizer was selected as perpendicular to the rubbing direction, i.e. ϕ_{P2} = 15°. Accordingly, a normal closed characteristics was obtained.

In the present embodiment, a liquid crystal, of which main component was a trifluoro compound containing three fluoro groups at terminals, having a specific resistivity of 1.0 x 10^{14} Ωcm and an average specific dielectric constant of 6.1 was used. While, silicon nitride (SiN) was used as for an insulating film, and its specific resistivity was 1.0 x 10^{12} Ωcm and specific dielectric constant was 8. As for an orienting film, a polyamide orienting film made from 2, 2-bis [4-(p-aminophenoxy) phenylpropane and pyromellitic acid dianhydride was used, and its specific resistivity was 2.2 x 10^{13} Ωcm and its average specific dielectric constant was 2.9.

Accordingly, respective products ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the liquid crystal layer, the insulating film, and the orienting film was less than 8 x 10^{15} Ωcm, and the ratio of the maximum value and the minimum value of the three bodies, $((\epsilon_r\rho)_{max} / (\epsilon_r\rho)_{min})$, was less than 100.

The active matrix type liquid crystal display device as obtained above was evaluated as rank 1 in the evaluation of residual image, and any residual image was not observed at all.

Embodiment 10

Composition of the present embodiment is the same as embodiment 1 except following subject matters;

The liquid crystal had a specific resistivity of 2.0 x 10^{11} Ωcm and an average specific dielectric constant of 6.5. Silicon nitride (SiN) was used as for the insulating film, and its specific resistivity was 3.0 x 10^{13} Ωcm and its specific dielectric constant was 8. As for the orienting film, a polyamide orienting film made from 2, 2-bis [4-(p-aminophenoxy) ph nylpropane and pyromellitic acid dianhydride was used, and its specific resistivity was 1.0 x 10^{13} Ωcm and its average specific dielectric constant was 2.9.

Accordingly, respective products ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the liquid crystal layer, the insulating film, and the orienting film were less than 8 x 10^{15} Ωcm.

The active matrix type liquid crystal display device as obtained above was evaluated as rank 3 in the evaluation of residual image, and residual image time was within five minutes.

Embodiment 11

Composition of the present embodiment is the same as embodiment 2 except following subject matters;

The liquid crystal had a specific resistivity of 2.0 x 10^{14} Ωcm and an average specific dielectric constant of 6.1. Silicon dioxide (SiO_2) was used as for the insulating film, and its specific resistivity was 1.0 x 10^{13} Ωcm and its specific dielectric constant was 8. As for the orienting film, a polyamide orienting film made from 2, 2-bis [4-(p-aminophenoxy) phenylpropane and pyromellitic acid dianhydride was used, and its specific resistivity was 2.0 x 10^{12} Ωcm and its average specific dielectric constant was 2.9.

Accordingly, respective products ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the liquid crystal layer, the insulating film, and the orienting film was less than 8 x 10^{15} Ωcm. The active matrix type liquid crystal display device as obtained above was evaluated as rank 4 in the evaluation of residual image, and residual image time was within five minutes.

Embodiment 12

Composition of the present embodiment is the same as embodiment 2 except following subject matters;

The liquid crystal had a specific resistivity of 2.0 x 10^{13} Ωcm and an average specific dielectric constant of 6.1. Silicon nitride (SiN) was used as for the insulating film, and its specific resistivity was 1.0 x 10^{15} Ωcm and its specific dielectric constant was 8. The orienting film was formed with a compound RN-718 (made by Nissan Chemical Co.), and its specific resistivity was 3.2 x 10^{12} Ωcm and its average specific dielectric constant was 3.1.

Accordingly, respective products ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the liquid crystal layer, the insulating film, and the orienting film was less than 8 x 10^{15} Ωcm. The active matrix type liquid crystal display devic as

obtained above was evaluated as rank 4 in the evaluation of residual image, and residual image time was within five minutes.

Embodiment 13

FIGs. 5 indicate a structure of electrode for a picture element unit in the thirteenth embodiment of the present invention. A thin film transistor 15 was composed of a picture element electrode 4, a signal electrode 3, a scanning electrode 13, and amorphous silicon 14. A common electrode 5 was in a same layer with the scanning electrode, and a pattern was made of a same metal layer. Further, the picture element electrode and the signal electrode were formed by a pattern made of a same metal. A capacitance element is formed as a structure wherein a gate silicon nitride (gate SiN) film 6 is inserted between the picture element electrode and the common electrode in a region where the two common electrodes 5 are connected. The picture element electrode is arranged between the two common electrodes 5 as shown as a plan cross section in FIG. 5, A-A' cross section. The picture element has pitches of 69 µm in a horizontal direction (i.e. between signal wiring electrodes) and 207 µm in a vertical direction (i.e. between scanning wiring electrodes). Width of all the electrodes is 10 µm, respectively.

While, in order to improve an opening fraction, the signal wiring electrode of the picture element electrode formed independently for a picture element unit and common electrode in a direction along a longitudinal direction of the signal wiring electrode had somewhat narrower width at an extended portion, that were, respectively 5 µm and 8 µm. In order to realize a larger opening fraction as possible, the common electrode and the signal electrode were overlapped somewhat (1 µm) through intermediary of the insulating film.

Accordingly, a black matrix structure 16 wherein light was shielded only in a direction along the scanning wiring electrode was adopted. In accordance with the above described manner, a gap between the common electrode became 20 µm, a longitudinal length of the opening became 157 µm, and consequently, a large opening fraction such as 44.0 % was obtained.

The number of picture elements was 320 x 160 with 320 signal wiring electrodes and 160 wiring electrodes.

A driving LSI was connected to the panel as shown in FIG. 7, a vertical scanning circuit 20 and an image signal driving circuit 21 were connected to TFT substrate, and the active matrix was driven by being supplied scanning signal voltage, image signal voltage, and timing signal from a power source circuit and a controller 22.

In the present embodiment, an insulating film of 0.4 µm thick was formed with silicon nitride (SiN). As for the orienting film, a polyamide orienting film made from 4, 4'-diaminodiphenylether and pyromellitic acid dianhydride was used. Thickness of the orienting film was 0.1 µm, and accordingly, total thickness of the insulating film and the orienting film was 0.5 µm.

Between the substrates, a nematic liquid crystal composition having a positive dielectric anisotropy $\Delta\epsilon$ of 4.5 and birefringence Δn of 0.072 (589 nm, 20 °C) was inserted.

Drawn direction of the upper and the lower boundary planes were approximately parallel mutually, and formed an angle of 95 degrees ($\phi_{LC1} = \phi_{LC2} = 95°$) to a direction of supplied electric field. A gap d was kept by holding dispersed spherical polymer beads between the substrates at 4.5 µm interval under a liquid crystal filled condition. Therefore, $\Delta n \cdot d$ is 0.324 µm. The panel was held between two polarizer (made by Nitto Denko Co., G1220DU), polarizing light transmitting axis of one of the polarizer was selected as approximately parallel to the rubbing direction, i.e. $\phi_{P1} = 95°$, and the axis of another polarizer was selected as perpendicular to the rubbing direction, i.e. $\phi_{P2} = 5°$. Accordingly, a normal closed characteristics was obtained.

Residual image of the active matrix liquid crystal display device obtained by the above explained manner was evaluated as rank 1 as shown in FIG. 10, and any residual image was not observed at all. Further, transparency of the insulating film and the orienting film maintained more than 90 % transmission factor as shown in FIG. 11. The transparency was evaluated by the transmission factor at 400 nm.

Embodiment 14

Composition of the present embodiment is the same as embodiment 13 except following subject matters;

In the present embodiment, silicon dioxide (SiO_2) was used as for the insulating film, and its thickness was 1.2 µm. As for the orienting film, a polyamide orienting film made from 4, 4'-diaminodiphenylether and pyromellitic acid dianhydride was used. Thickness of the orienting film was 0.3 µm, and accordingly, total thickness of the insulating film and the orienting film was 1.5 µm.

Residual image of the active matrix liquid crystal display device obtained in the above manner was evaluated as rank 1 as shown in FIG. 10, and any residual image was not observed at all. Further, transparency of the insulating film and the orienting film maintained more than 90 % transmission factor as shown in FIG. 11.

Embodiment 15

Composition of the present embodiment is the same as embodiment 13 except following subject matters;

In the present embodiment, the orienting film had a double layer structure comprising inorganic silicon nitride (SiN) and organic epoxy resin. Thickness of the silicon nitride layer and the epoxy resin layer was 1.0 µm and 0.6 µm, respectively. Further, as for the orienting film, an orienting film composition RN-718 (made by Nissan Chemical Co.) was used, and its thickness was 0.2 µm. Accordingly, total thickness of the insulating film and the orienting film was 1.8 µm.

Residual image of the active matrix liquid crystal display device obtained in the above manner was evaluated as rank 1 as shown in FIG. 10, and any residual image was not observed at all. Further, transparency of the insulating film and the orienting film maintained more than 90 % transmission factor as shown in FIG. 11.

Embodiment 16

Composition of the present embodiment is the same as embodiment 13 except following subject matters;

In the present embodiment, the orienting film had a double layer structure comprising inorganic silicon nitride (SiN) and organic epoxy resin. Thickness of the silicon nitride layer and the epoxy resin layer was 0.3 µm and 1.5 µm, respectively. Further, as for the orienting film, an orienting film composition RN-718 (made by Nissan Chemical Co.) was used, and its thickness was 0.2 µm. Accordingly, total thickness of the insulating film and the orienting film was 2.0 µm.

Residual image of the active matrix liquid crystal display device obtained in the above manner was evaluated as rank 1 as shown in FIG. 10, and any residual image was not observed at all. Further, transparency of the insulating film and the orienting film maintained more than 90 % transmission factor as shown in FIG. 11.

Embodiment 17

Composition of the present embodiment is the same as embodiment 13 except following subject matters;

In the present embodiment, silicon dioxide (SiO_2) was used as for the insulating film, and its thickness was 0.2 µm. As for the orienting film, a polyamide orienting film made from 4, 4'-diaminodiphenylether and pyromellitic acid dianhydride was used. Thickness of the orienting film was 2.0 µm, and accordingly, total thickness of the insulating film and the orienting film was 2.2 µm.

Residual image of the active matrix liquid crystal display device obtained in the above manner was evaluated as rank 1 as shown in FIG. 10, and any residual image was not observed at all. Further, transparency of the insulating film and the orienting film maintained more than 90 % transmission factor as shown in FIG. 11.

Embodiment 18

Composition of the present embodiment is the same as embodiment 13 except following subject matters;

In the present embodiment, epoxy resin was used as for the insulating film, and its thickness was 1.8 µm. As for the orienting film, a polyamide orienting film made from 2, 2-bis [4-(p-aminophenoxy) phenylpropane and pyromellitic acid dianhydride was used, and its thickness was 0.5 µm. Accordingly, total thickness of the insulating film and the orienting film was 2.3 µm.

Residual image of the active matrix liquid crystal display device obtained in the above manner was evaluated as rank 1 as shown in FIG. 10, and any residual image was not observed at all. Further, transparency of the insulating film and the orienting film maintained more than 90 % transmission factor as shown in FIG. 11.

Embodiment 19

Composition of the present embodiment is the same as embodiment 13 except following subject matters;

In the present embodiment, the insulating film and the orienting film were made of the same material. That means, a polyamide orienting film made from 2, 2-bis [4-(p-aminophenoxy) phenylpropane and pyromellitic acid dianhydride, which has both functions for the insulating film and the orienting film, was applied 2.8 µm thick.

Residual image of the active matrix liquid crystal display device obtained in the above manner was evaluated as rank 1 as shown in FIG. 10, and any residual image was not observed at all. Further, transparency of the insulating film and the orienting film maintained more than 90 % transmission factor as shown in FIG. 11.

Embodiment 20

Composition of the present embodiment is the same as embodiment 13 except following subject matters;

A color filter was formed in the insulating film. First, silicon nitride (SiN) film was formed, and the color filter was provided on the silicon nitride film

by printing. Further, epoxy resin was applied in order to flatten the film surface. Subsequently, the orienting film was formed by applying an orienting film composition RN-718 (made by Nissan Chemical Co.).

Thickness of the silicon nitride layer and the epoxy resin layer was 0.3 µm and 1.5 µm, respectively. Further, the orienting film composition was applied 0.2 µm thick.

Residual image of the active matrix liquid crystal display device obtained in the above manner was evaluated as rank 1 as shown in FIG. 10, and any residual image was not observed at all. Further, transparency of the insulating film and the orienting film maintained more than 90 % transmission factor as shown in FIG. 11.

Embodiment 21

Composition of the present embodiment is the same as embodiment 20 except following subject matters;

In order to make the orienting film surface abutting to the liquid crystal more flat, the epoxy resin layer was made 0.3 µm thick and the orienting film composition Rn-718 was applied 0.7 µm thick. Accordingly, flatness of the surface was improved, and lapping treatment was performed more uniformly because of decreased steps at the surface. As a result, light leakage was eliminated.

Residual image of the active matrix liquid crystal display device obtained in the above manner was evaluated as rank 1 as shown in FIG. 10, and any residual image was not observed at all. Further, contrast was increased larger than that of the embodiment 17.

Embodiment 22

Composition of the present embodiment is the same as embodiment 20 except following subject matters;

Printability of polyamide orienting film on epoxy resin layer is not necessarily preferable. Therefore, inorganic silicon nitride (SiN) film 0.3 µm thick was formed on an epoxy resin layer 1.5 µm thick which was applied for flattening of the color filter and as for the insulating film. Therefore, printability of the orienting film was improved. At that time, the orienting film composition RN-718 was applied 0.1 µm thick.

Residual image of the active matrix liquid crystal display device obtained in the above manner was evaluated as rank 1 as shown in FIG. 10, any residual image was not observed at all, contrast was increased larger than that of the embodiment 17, and production yield was increased by improvement of printability of the orienting film.

Embodiment 23

FIG. 6 indicates a structure of electrode for a picture element unit in the twenty third embodiment of the present invention. In the present embodiment, thin film transistors were not provided to the picture element units. A scanning signal electrode 13 and a signal electrode 3 were in different layers mutually. Each electrodes were connected respectively to a scanning circuit driver and an image signal circuit driver, and the matrix was driven in a simple time-shared manner.

Drawn directions of the upper and the lower boundary planes were approximately parallel mutually, and formed an angle of 105 degrees ($\phi_{LC1} = \phi_{LC2} = 105°$) to a direction of supplied electric field (FIG. 2). A gap d was kept by holding dispersed spherical polymer beads between the substrates at 4.2 µm interval under a liquid crystal filled condition. The panel was held between two polarizer (made by Nitto Denko Co., G1220DU), polarizing light transmitting axis of one of the polarizer was selected as approximately parallel to a rubbing direction, i.e. $\phi_{P1} = 105°$, and the axis of another polarizer was selected as perpendicular to the rubbing direction, i.e. $\phi_{P2} = 15°$. Accordingly, a normal closed characteristics was obtained.

As for the orienting film, silicon nitride (SiN) film 0.7 µm thick was formed. And the orienting film of RN-422 (made by Nissan Chemical Co.) was formed 0.9 µm thick on the insulating film.

The active matrix type liquid crystal display device as obtained above was evaluated as rank 1 in the evaluation of residual image, and any residual image was not observed at all. Further, transparency of the insulating film and the orienting film maintained more than 90 % transmission factor as shown in FIG. 11.

Embodiment 24

Composition of the present embodiment is the same as embodiment 10 except following subject matters;

In the present embodiment, silicon nitride (SiN) film was used as for the insulating film, and its thickness was 0.3 µm. As for the orienting film, a polyamide orienting film made from 4, 4'-diaminodiphenylether and pyromellitic acid dianhydride was used. Thickness of the orienting film was 0.1 µm, and accordingly, total thickness of the insulating film and the orienting film was 0.4 µm.

Residual image of the active matrix liquid crystal display device obtained in the above manner was evaluated as rank 3 as shown in FIG. 10, and residual image time was within five minutes. Further, transparency of the insulating film and the orienting film maintained more than 90 % transmis-

sion factor as shown in FIG. 11.

Organic films used in the present invention for the insulating film and the orienting film are not restricted by the organic polymers described in the embodiments. In addition to polyamide and epoxy group polymers, polyesters, polyurethanes, polyvinyl alcohols, polyamides, silicones, acrylates, olefin-sulfon group polymers, and the like can be used irrelevant to its photosensitivity. Further, surface treating agents, for instance, such as amino group silane coupling agents as γ-aminopropyl triethoxysilane, δ-aminopropyl methyldiethoxysilane, and N-β(aminoethyl) γ-aminopropyltrimethoxysilane, epoxy group silane coupling agents, titanate coupling agents, aluminum alcoholates, aluminum chelates, and zirconium chelates can be mixed or reacted with the organic polymers. But, the present invention is not restricted by the above examples.

Further, material for the inorganic film is not restricted only silicon nitride and silicon dioxide, but also germanium nitride, germanium oxide, aluminum nitride, and aluminum oxide can be used. However, the present invention is not restricted by the above examples.

Comparative example 1

Composition of the present embodiment is the same as embodiment 2 except following subject matters;

The liquid crystal had a specific resistivity of 2.0×10^{14} Ωcm and an average specific dielectric constant of 6.1. Silicon nitride (SiN) was used as for the insulating film, and its specific resistivity was 6×10^{15} Ωcm and its specific dielectric constant was 8. As for the orienting film, a polyamide orienting film made from 2, 2-bis [4-(p-aminophenoxy) phenylpropane and pyromellitic acid dianhydride was used, and its specific resistivity was 2.0×10^{12} Ωcm and its average specific dielectric constant was 2.9.

Accordingly, respective products ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the liquid crystal layer and the orienting film was less than 8×10^{15} Ωcm, but product ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the insulating film was larger than 8×10^{15} Ωcm.

The active matrix type liquid crystal display device as obtained above was evaluated as rank 5 in the evaluation of residual image, and residual image time was beyond five minutes.

Comparative example 2

Composition of the present embodiment is the same as embodiment 2 except following subject matters;

The liquid crystal had a specific resistivity of 6.3×10^{12} Ωcm and an average specific dielectric constant of 6.1. Silicon nitride (SiN) was used as for the insulating film, and its specific resistivity was 2×10^{15} Ωcm and its specific dielectric constant was 8. As for the orienting film, a polyamide orienting film made from 2, 2-bis [4-(p-aminophenoxy) phenylpropane and pyromellitic acid dianhydride was used, and its specific resistivity was 5.5×10^{12} Ωcm and its average specific dielectric constant was 2.9.

Accordingly, respective products ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the liquid crystal layer and the orienting film was less than 8×10^{15} Ωcm, but product ($\epsilon_r\rho$) of specific resistivity ρ and specific dielectric constant ϵ_r of the insulating film was larger than 8×10^{15} Ωcm.

The active matrix type liquid crystal display device as obtained above was evaluated as rank 5 in the evaluation of residual image, and residual image time was beyond five minutes.

Comparative example 3

Composition of the present embodiment is the same as embodiment 10 except following subject matters;

In the present embodiment, silicon nitride (SiN) was used as for the insulating film, and its thickness was 2.1 µm. As for the orienting film, a polyamide orienting film made from 4, 4'-diaminodiphenylether and pyromellitic acid dianhydride was used. Thickness of the orienting film was 1.0 µm, and accordingly, total thickness of the insulating film and the orienting film was 3.1 µm.

Residual image of the active matrix liquid crystal display device obtained in the above manner was evaluated as rank 1 as shown in FIG. 10(a), but transparency of the insulating film and the orienting film was less than 90 % transmission factor as shown in FIG. 10 (b).

Comparative example 4

Composition of the present embodiment is the same as embodiment 10 except following subject matters;

In the present embodiment, silicon nitride (SiN) was used as for the insulating film, and its thickness was 0.1 µm. As for the orienting film, the RN-718 was used. Thickness of the orienting film was 0.1 µm, and accordingly, total thickness of the insulating film and the orienting film was 0.2 µm.

The active matrix type liquid crystal display device as obtained above was evaluated as rank 5 in the evaluation of residual image, and residual image time was beyond five minutes.

In accordance with the present invention, a liquid crystal display device of a high picture quality with substantially eliminated residual image can be obtained by making brightness recovering time within five minutes after displaying a same figure and/or character pattern for 30 minutes.

Claims

1. Liquid crystal display device, comprising:

   display picture elements each being composed of electrodes (3, 4, 5) on a substrate (1),

   an orienting film (8) for the liquid crystal layer (12) formed on the substrate (1) directly or via an insulating layer (7),

   said substrate (1) being arranged such as to face another substrate (1) on which another orienting film (8) is formed,

   the liquid crystal layer (12) being held between the two substrates (1),

   the electrodes being arranged such as to generate an electric field (9) substantially parallel to the substrate (1) and to the liquid crystal layer (12), and being

   connected to external control means (20, 21, 22), and

   polarizing means (2) for changing the optical characteristics of the liquid crystal layer (12),

   characterized in that it has

   a brightness recovering time of not greater than 5 min, the brightness recovering time being the time until the brightness of a displayed portion that has been displayed for 30 min and is then turned off, returns to the background brightness.

2. The liquid crystal display device according to claim 1, characterized in that

   the respective products $(\epsilon_r\rho)_{LC}$, $(\epsilon_r\rho)_{AF}$ and/or $(\epsilon_r\rho)_{PAS}$ of the specific dielectric constant ϵ_r and the specific resistivity ρ of the liquid crystal layer (12), the orienting film (8) and/or the insulating film (7) are within the range of 1×10^9 to 8×10^{15} $\Omega\cdot$cm.

3. The liquid crystal display device according to claim 1 and/or 2,
   characterized in that

   the orienting film (8) and/or the insulating film (7) have a surface resistance of 3.0×10^{11} to 2.5×10^{18} $\Omega/\square$.

4. The liquid crystal display device according to one or more of claims 1 to 3,
   characterized in that it has

   approximately similar values of the products $(\epsilon_r\rho)_{LC}$, $(\epsilon_r\rho)_{AF}$ and/or $(\epsilon_r\rho)_{PAS}$ of the specific dielectric constant ϵ_r and the specific resistivity ρ of the respective liquid crystal layer (12), the orienting film (8) and/or the insulating film (7).

5. The liquid crystal display device according to one or more of claims 1 to 4,
   characterized in that

   the ratio of the maximum value to the minimum value of the respective products $(\epsilon_r\rho)_{LC}$, $(\epsilon_r\rho)_{AF}$ and/or $(\epsilon_r\rho)_{PAS}$ of the specific dielectric constant ϵ_r and the specific resistivity ρ of the liquid crystal layer (12), the orienting film (8) and/or the insulating film (7) is 1 to 100.

6. The liquid crystal display device according to one or more of claims 1 to 5,
   characterized in that

   the respective products $(\epsilon_r\rho)_{LC}$, $(\epsilon_r\rho)_{AF}$ and/or $(\epsilon_r\rho)_{PAS}$ of the specific dielectric constant ϵ_r and the specific resistivity ρ of the liquid crystal layer (12), the orienting film (8) and/or the insulating film (7) have a relationship expressed by the following equations (1) to (3):

   $0.1 \leq (\epsilon_r\rho)_{LC}/(\epsilon_r\rho)_{AF} \leq 10$ (1)

   $0.1 \leq (\epsilon_r\rho)_{LC}/(\epsilon_r\rho)_{PAS} \leq 10$ (2)

   $0.1 \leq (\epsilon_r\rho)_{AF}/(\epsilon_r\rho)_{PAS} \leq 10$ (3).

7. The liquid crystal display device according to one or more of claims 1 to 6, wherein the display picture elements are composed of scanning signal electrodes, image signal electrodes, picture element electrodes, and active elements on the substrate (1).

8. The liquid crystal display device according to one or more of claims 1 to 7,
   characterized by one or more of the following features:

   The sum of the film thickness of the orienting film (8) and of the insulating film (7) on the substrate (1) is 0.5 to 3 μm;

   the film thickness of the insulating film (7) is 0.4 to 2 μm;

   the orienting film (8) is made of an organic material, and the insulating film (7) is made of an inorganic material;

   the orienting film (8) is made of an organic material, and the insulating film (7) has a double-layer structure of an inorganic material and an organic material;

   the orienting film (8) is made of an organic material; and the insulating film (7) is made of

an inorganic material, and the layer composed of the organic material is thicker than the layer composed of the inorganic material;

both the orienting film (8) and the insulating film (7) are made of an organic material;

the surface plane of the orienting film (8) abutting on the liquid crystal layer (12) is flat;

both the orienting film (8) and the insulating film (7) are made of the same material;

a color filter is provided on either one of the substrates (1), and the insulating film (7) is provided between the color filter and the liquid crystal layer (12);

a flattening film having the function to flatten steps on the color filter surface made of an organic material is provided and an inorganic film is formed on the flattening film;

an orienting film (8) on a substrate (1) having a color filter is formed via a layer composed of an inorganic material.

9. The liquid crystal display device according to one or more of claims 1 to 8,
characterized in that

a color filter is formed on the substrate (1) which has scanning signal electrodes, image signal electrodes, picture element electrodes, and active elements forming the picture elements, and the insulating film (7) is provided between the color filter and the liquid crystal layer (12).

10. The liquid crystal display device according to one or more of claims 1 to 9,
characterized in that

means for inputting information, means for calculating or processing that information in a predetermined manner, a device for the output of the processed information, a device for storing the processed information, and an internal power source are provided.

FIG. 1(a)

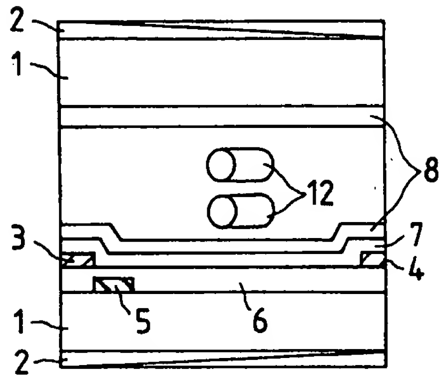


FIG. 1(b)

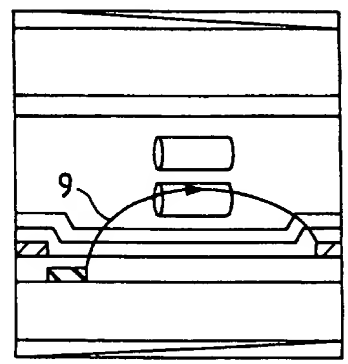


FIG. 1(c)

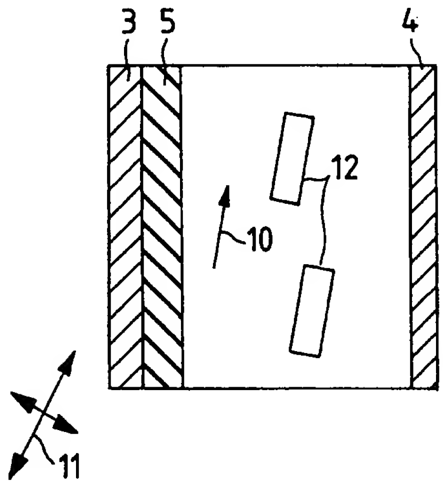


FIG. 1(d)

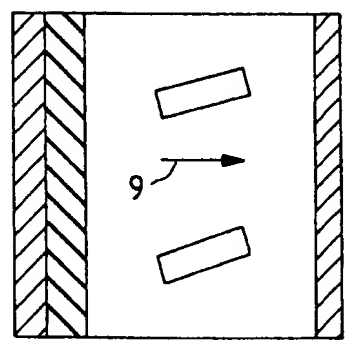


FIG. 2

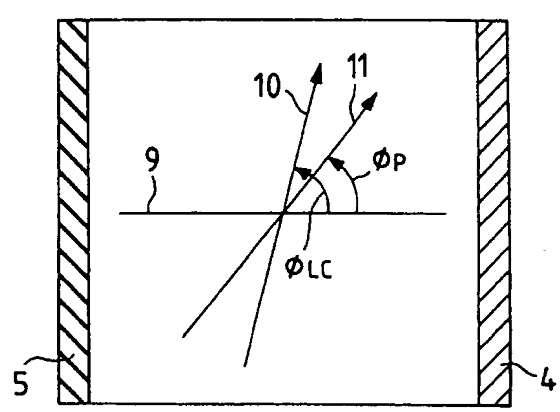


FIG. 3

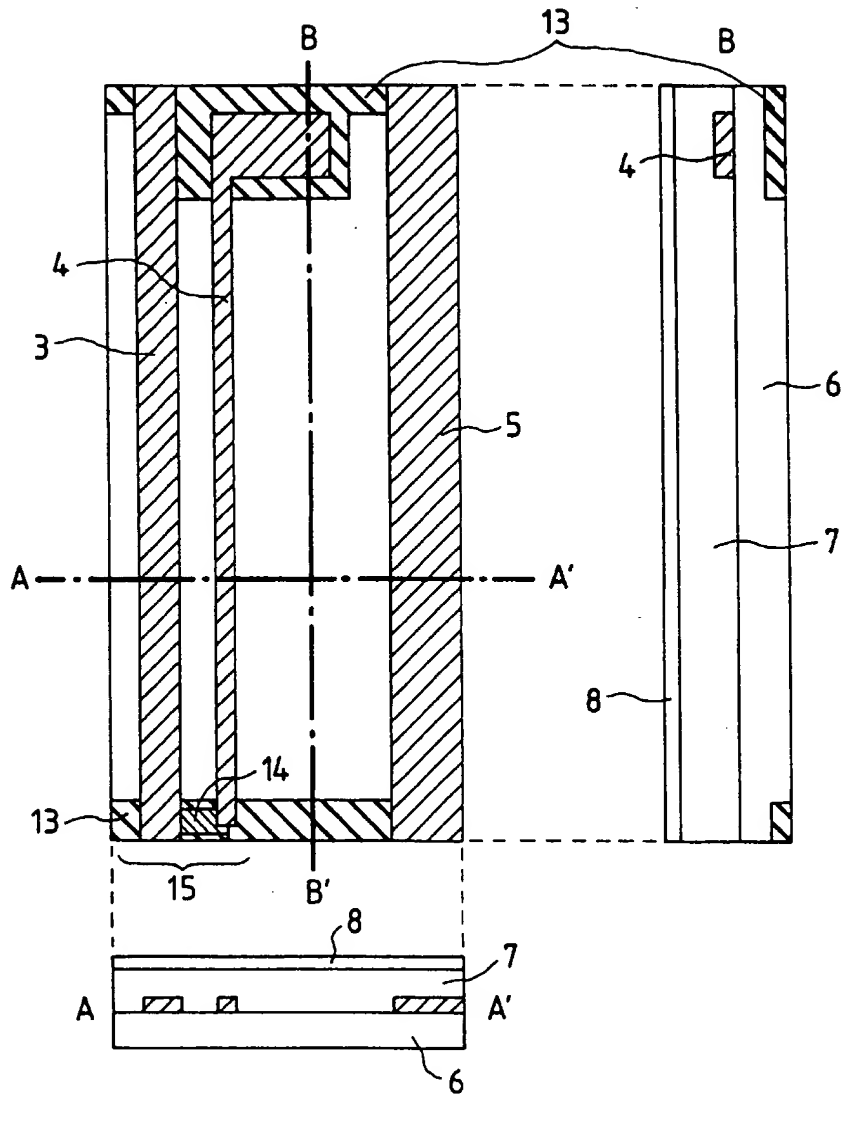
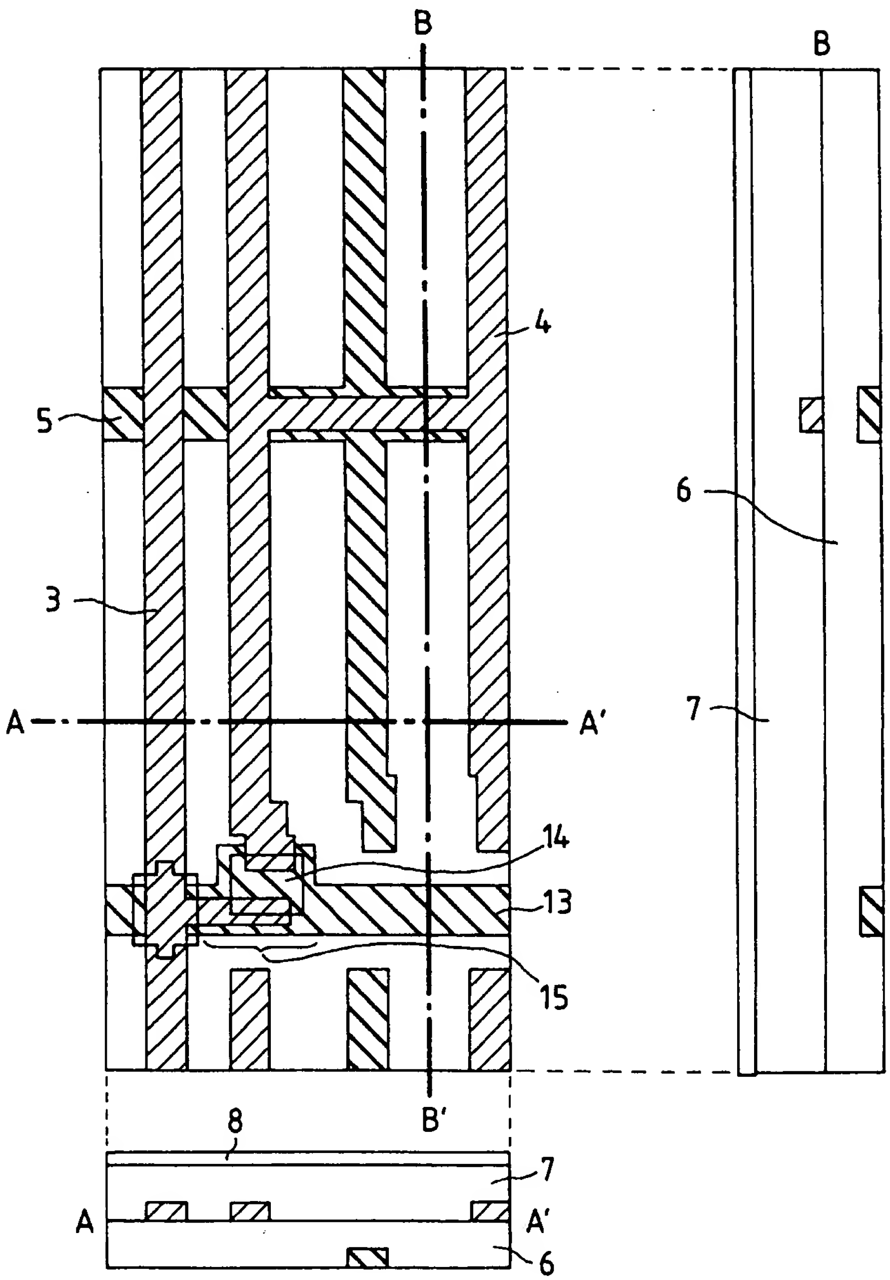
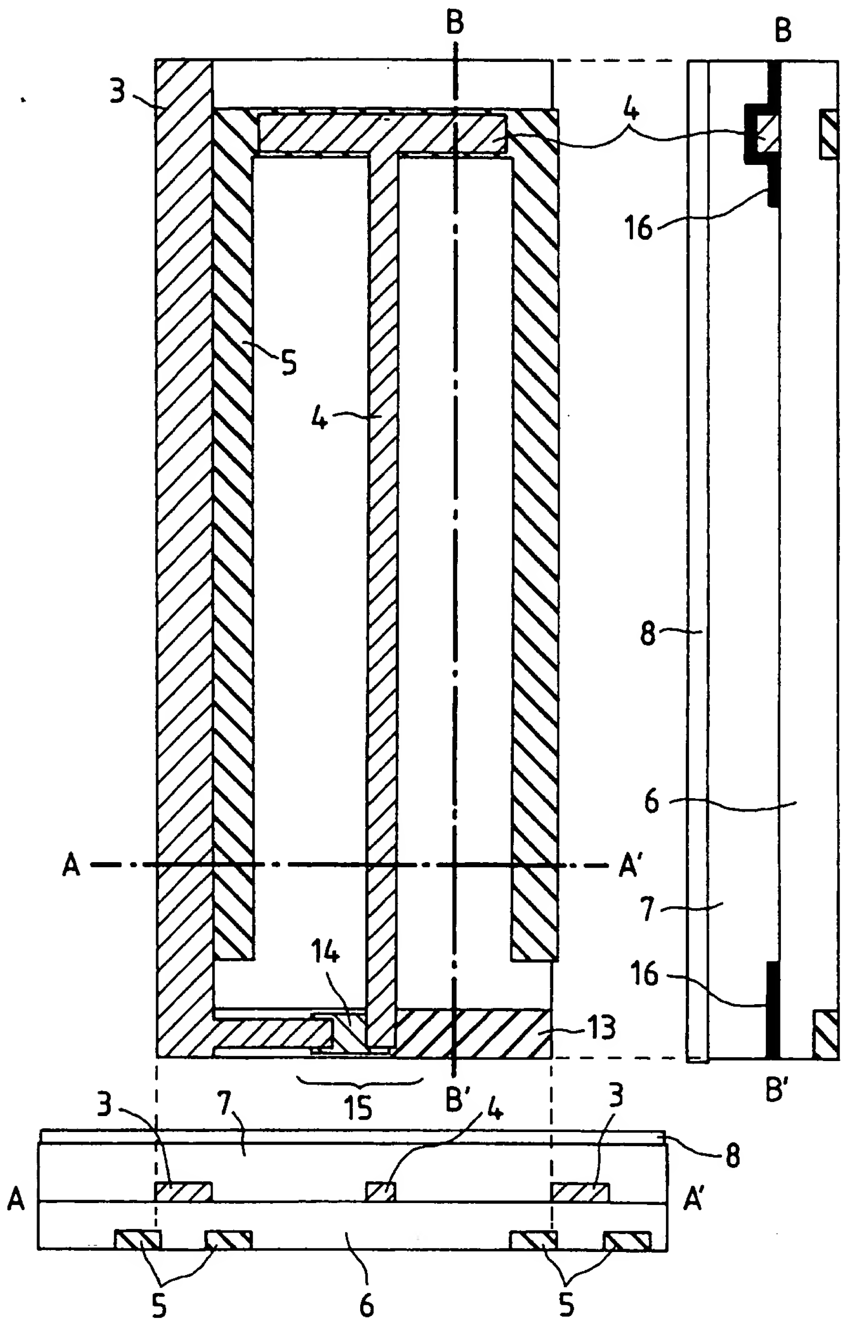


FIG. 4



WEST

FIG. 5



WEST

FIG. 6

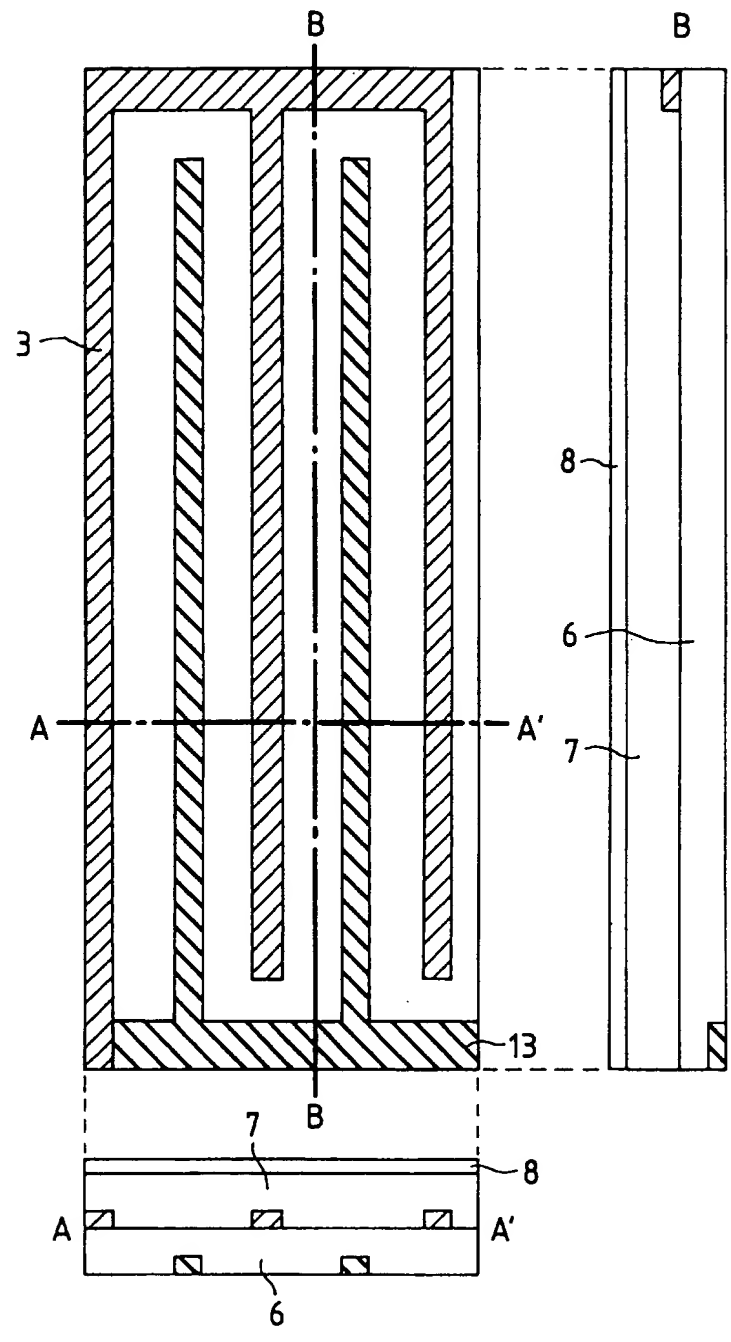


FIG. 7

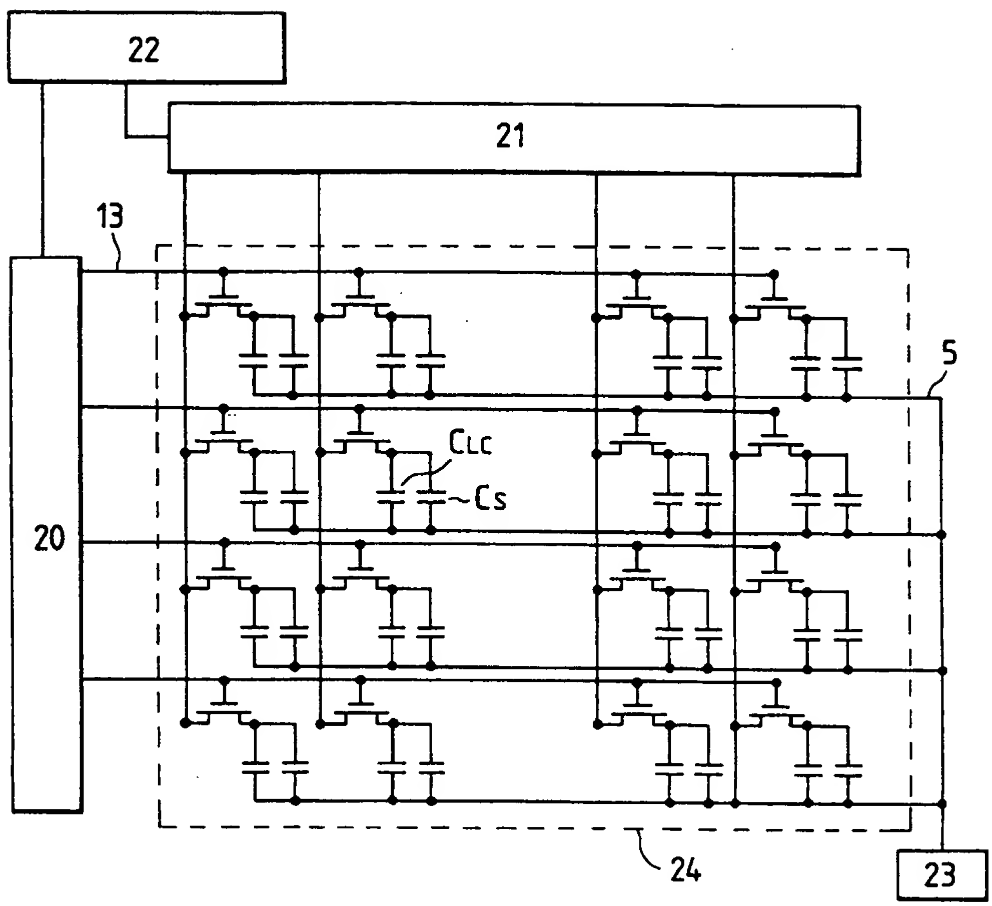
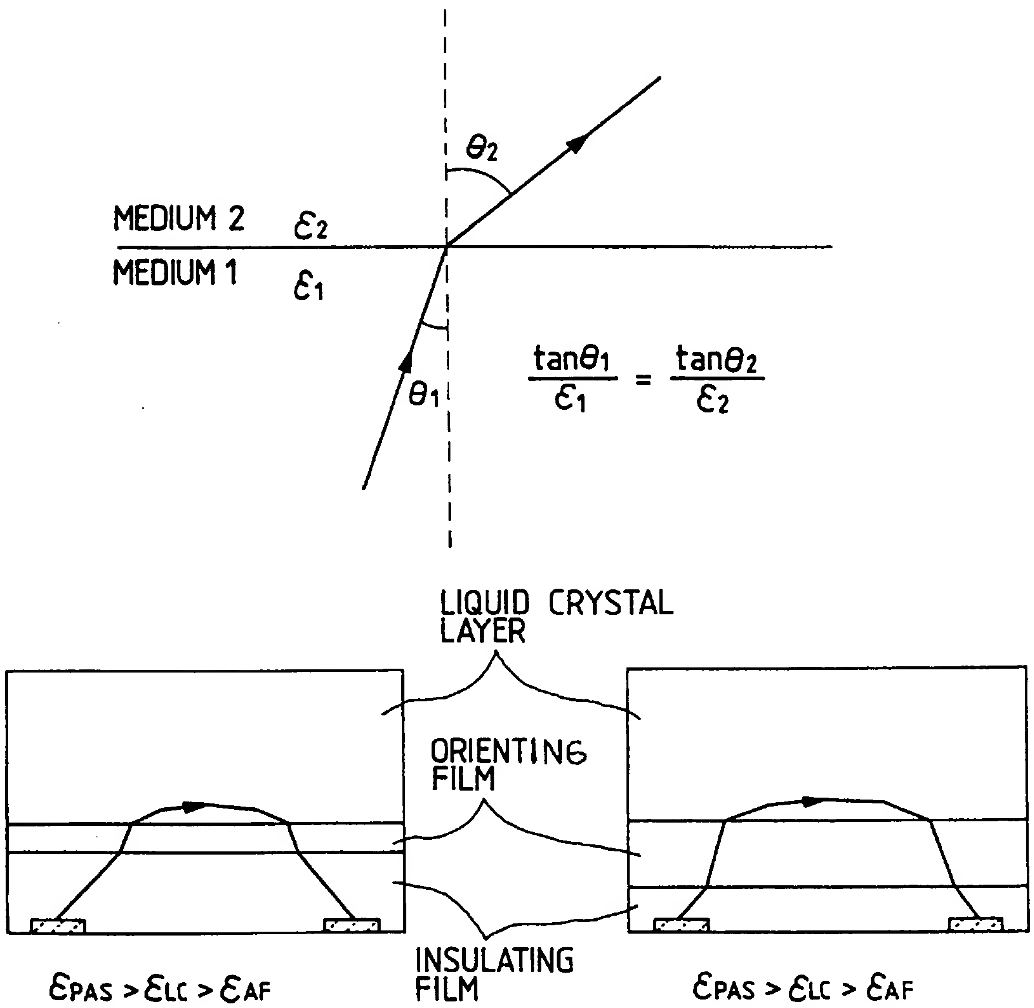


FIG. 8



θ_2
MEDIUM 2
ε_2
MEDIUM 1
ε_1
θ_1
$\frac{\tan\theta_1}{\varepsilon_1} = \frac{\tan\theta_2}{\varepsilon_2}$
LIQUID CRYSTAL LAYER
ORIENTING FILM
INSULATING FILM
$\varepsilon_{PAS} > \varepsilon_{LC} > \varepsilon_{AF}$
$\varepsilon_{PAS} > \varepsilon_{LC} > \varepsilon_{AF}$

FIG. 9(a)

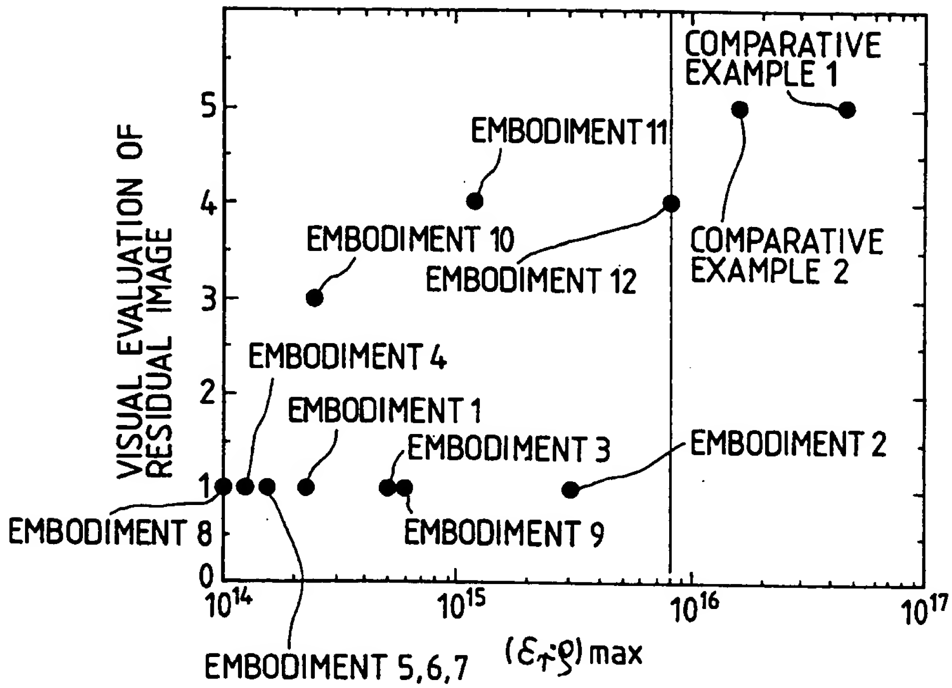

COMPARATIVE EXAMPLE 1
EMBODIMENT 11
EMBODIMENT 10
EMBODIMENT 12
COMPARATIVE EXAMPLE 2
EMBODIMENT 4
EMBODIMENT 1
EMBODIMENT 3
EMBODIMENT 2
EMBODIMENT 8
EMBODIMENT 9
EMBODIMENT 5,6,7
VISUAL EVALUATION OF RESIDUAL IMAGE
0
1
2
3
4
5
10^{14}
10^{15}
10^{16}
10^{17}
$(\varepsilon_T \cdot \rho)$ max

FIG. 9(b)

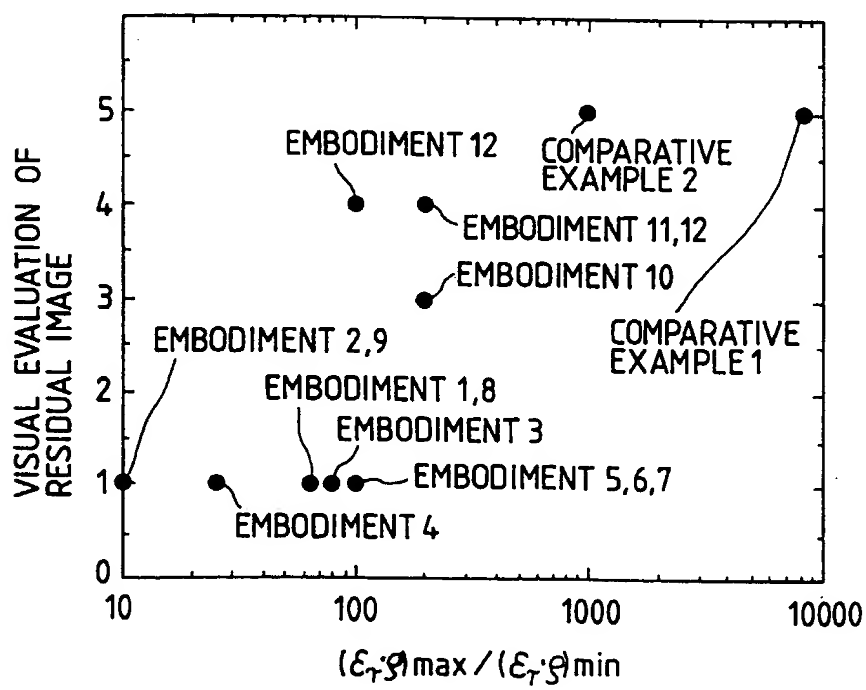

EMBODIMENT 12
COMPARATIVE EXAMPLE 2
EMBODIMENT 11,12
EMBODIMENT 10
COMPARATIVE EXAMPLE 1
EMBODIMENT 2,9
EMBODIMENT 1,8
EMBODIMENT 3
EMBODIMENT 5,6,7
EMBODIMENT 4
VISUAL EVALUATION OF RESIDUAL IMAGE
0
1
2
3
4
5
10
100
1000
10000
$(\varepsilon_T \cdot \rho)$ max / $(\varepsilon_T \cdot \rho)$ min

FIG. 10(a)

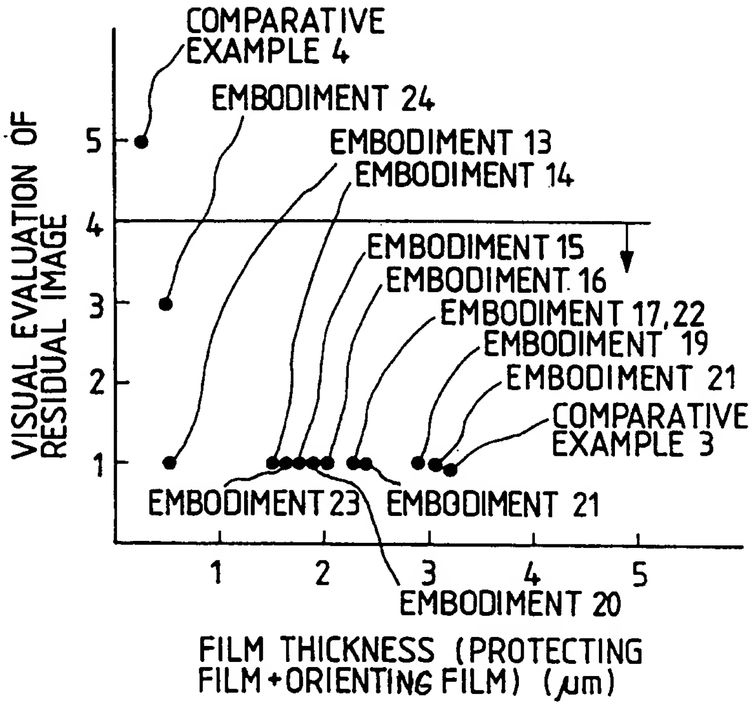


FIG. 10(b)

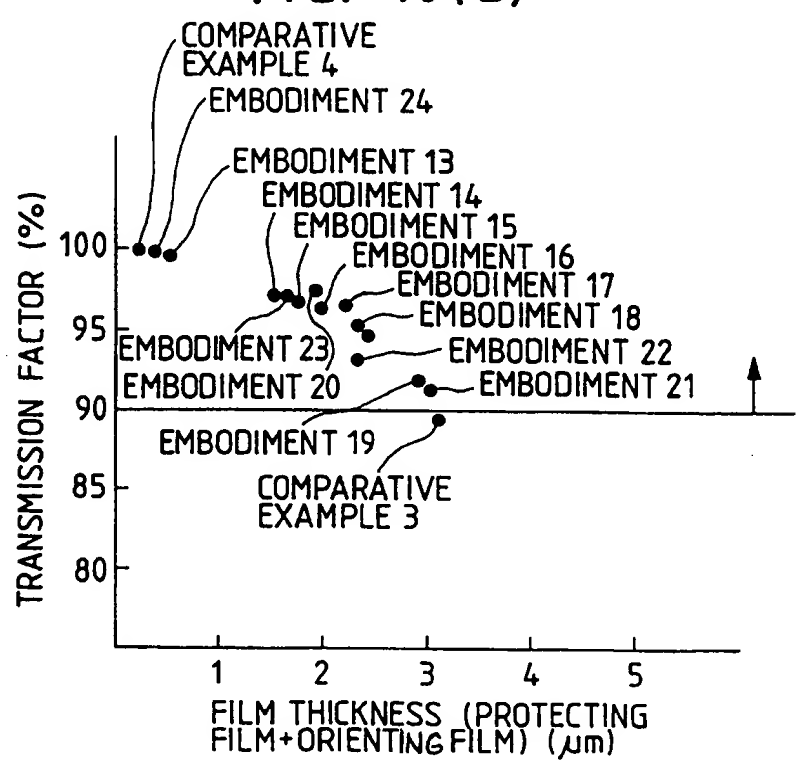


FIG. 11(a)

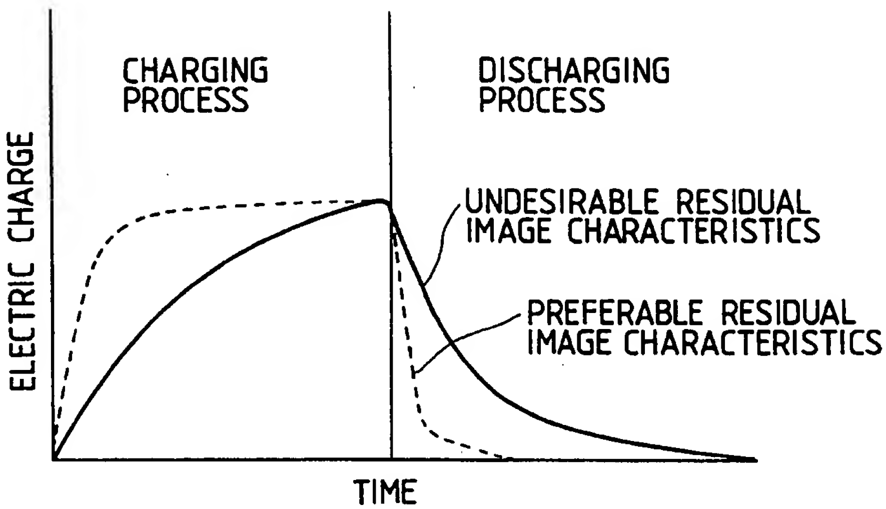


FIG. 11(b)